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ORIGINAL RESEARCH

SHOULDER EXTERNAL ROTATOR STRENGTH IN RESPONSE TO VARIOUS SITTING POSTURES: A CONTROLLED LABORATORY STUDY

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ABSTRACT

Background: The forward head rounded shoulder (FHRS) sitting posture has been associated with decreased shoulder complex muscle strength and function. Upon clinical observation, the adverse effects of the FHRS sitting posture on shoulder complex isometric muscle strength is also present when testing controls for scapular position.

Hypothesis/Purpose: The purpose of the study was to assess the effect of various sitting postures on shoulder external rotator muscle isometric strength when the strength testing controls for scapular position.

Study Design: A cohort study, with subjects serving as their own controls.

Methods: One hundred subjects ages 20-26 participated in the study. Each subject was placed in a neutral cervical sitting (NCS) posture which was maintained for five minutes after which the strength of the dominant shoulder external rotators was immediately tested with the glenohumeral joint in the neutral position using a Micro-FET3 Hand Held Muscle Testing Dynamometer (HHMTD). Each subject was returned to the NCS posture for subsequent external rotator strength testing after five minutes in a FHRS sitting posture, five additional minutes in the NCS posture and five minutes in a retracted cervical sitting (RCS) posture resulting in each subjects' external rotator strength being tested on four occasions. Subjects were randomized for order between the FHRS and RCS postures.

Results: Mean strength values for each condition were normalized to the mean strength value for the 1st NCS condition for each subject. A statistically significant decline in shoulder external rotator strength following the FHRS sitting posture occurred compared to the appropriate postural conditions ($p < .05$). A frequency analysis revealed that 36% of the subjects demonstrated greater than 10% decline in external rotator strength following five minutes in the FHRS sitting posture. The average percentage of strength decline in those with greater than a 10% reduction in external rotator strength was 19%. Sixty-four percent of the subjects experienced less than a 10% decline in shoulder external rotator strength in response to the FHRS sitting posture.

Conclusion: Shoulder external rotator strength declined 8% following five minutes in the FHRS sitting posture. A sub-population of 36% demonstrated an average decline of 19% in shoulder external rotator strength following five minutes in the FHRS sitting posture. The strength decline appears to resolve over the short-term by returning to the NCS posture.

Level of Evidence: Level III

Key Words: Sitting posture, shoulder external rotator strength

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INTRODUCTION

The forward head, rounded shoulder (FHRS) posture is routinely assumed by many individuals in modern society.[1,2] The FHRS posture is seen in the standing position but appears to be accentuated in relaxed sitting. Subsequently, the FHRS sitting posture is commonly assumed when driving, using a computer or hand held device, reading and viewing television to name only a few routine daily activities. The upper extremity consequences of the FHRS posture have been described as decreased shoulder complex range of motion, decreased shoulder muscle strength, and a reduction in subacromial space, each of which may contribute to shoulder dysfunction and possibly pain.[3-7]

Previous authors who have examined the influence of the FHRS posture on muscle isometric strength have focused on the position of the scapula and the resultant influence on shoulder muscle force production.[4-6,8] Kebaesta et al[4] reported a 16.2 % reduction in shoulder abductor muscle force produced in the sitting FHRS posture compared to the shoulder abductor force produced in a neutral sitting posture. In the Kebaesta study, isometric shoulder abduction was tested in the plane of the scapula at the horizontal position. Smith et al[5] reported an increase in isometric muscle force production of the shoulder flexors when tested with the shoulder at 90 degrees with the scapula maintained in a neutral position. This was compared to the isometric shoulder flexor muscle force produced when subjects were tested in both scapular protracted and retracted positions. In a subsequent study, Smith et al[6] reported a reduction in isometric force production of the shoulder external rotators when tested with the scapula protracted, the shoulder flexed to 90 degrees and externally rotated to 90 degrees. The magnitude of the decrease was 20% when compared to the isometric force produced during the neutral scapular position.[6] The cited studies suggest that scapular positions can influence shoulder muscle isometric force production.

The authors' clinical observations have also noted changes in shoulder external rotator muscle strength in apparent response to the maintenance of various sitting postures. The FHRS posture has been observed to result in a reduction in shoulder external rotator muscle strength while the erect neutral cervical sitting posture has been noted to favorably influence external rotator muscle strength.

Pheasant, in two prior case reports, described an immediate improvement in rotator cuff strength and reduction in signs and symptoms of subacromial impingement in response to cervical retraction and retraction with extension ROM exercises combined with neutral cervical posturing. The reported responses to the stated interventions also included an abolishment of the presenting painful arc of active shoulder abduction and negative Hawkins-Kennedy and Jobe empty can testing.[9] The author attributed the improved rotator cuff function to the changes in cervical position promoted by the cervical ROM exercises and neutral cervical posture positioning. The relationship reported by Pheasant among cervical retraction exercise, cervical retraction with extension exercise, neutral cervical posturing and the finding of improved rotator cuff strength prompted the authors to attempt to substantiate the observation through a systematic investigation. Specifically, the authors were interested in the influence the sustained position of the cervical spine had on the isometric strength of the shoulder external rotators.

The studies by Kebaesta et al[4] and Smith et al[5,6] focused on the influence the protracted scapula (rounded shoulder) that accompanies the FHRS posture, had on shoulder muscle force production. The current study, based on the case report by Pheasant, focused on the protruded position of the cervical spine (forward head) and the resulting influence on shoulder external rotator muscle strength. The influence of sitting cervical posture on shoulder muscle strength has not been reported in the literature to the best of the authors' knowledge. Therefore, the purpose of the study was to assess the effect of various sitting postures on shoulder external rotator muscle isometric strength when the strength testing controls for scapular position. The hypothesis is the FHRS sitting posture will have an adverse effect on shoulder external rotator muscle strength when the strength testing controls for scapular position.

METHODS

The design was a cohort study with the subjects serving as their own controls. Participants included a convenience sample of 100 healthy volunteers

Table 1. *Subject Profile*

Subject Profile	Mean	SD	Maximum	Minimum
Age (years)	22.65	±1.18	26	20
Height (inches)	66.75	±3.48	74	60
Weight (pounds)	160.72	±38.29	295	110

(39 males, 61 females) between 20 and 26 years of age from a university setting (Table 1). Individuals were excluded from participation for the following reasons: a prior history of spinal surgery; a history of neck or back pain with radiating symptoms into the arms or legs; current spinal pain; a history of dominant shoulder surgery or a history of dominant shoulder injury within the prior year.

The isometric external rotator strength of the dominant shoulder of each subject was tested following five minutes of sustained positioning under each of the following four conditions: 1.) neutral cervical sitting (NCS) posture, 2.) forward head rounded shoulder (FHRS) sitting posture, 3.) second neutral cervical sitting (NCS) posture and 4.) retracted cervical sitting (RCS) posture. The FHRS sitting posture and RCS posture were alternated for order with each successive subject to minimize learning and/or fatigue effects. For example; the first subject was positioned in the NCS posture for five minutes and then immediately tested, the FHRS sitting posture for five minutes and immediately tested, the NCS posture for an additional five minutes and immediately tested, and then finally the RCS posture for five minutes and immediately tested. The order of postures and testing for the second subject was NCS, RCS, NCS and FHRS. This alternating pattern of assignment was maintained throughout the testing of the 100 subjects.

The five-minute period of posture maintenance was determined to coincide with the time frame the authors' have observed strength changes to occur in response to various sitting postures in the clinic. Since the time frame for strength changes to occur in response to changes in sitting posture has not been formally objectified, five minutes was deemed a reasonable time frame to allow comparison of the four conditions listed above.

The NCS posture was defined by the vertical alignment of the tragus of the ear, bodies of the cervical vertebrae, acromion of the scapula, coronal mid-line of the thorax with the maintenance of the lumbar lordosis.[10] Due to the frontal plane posture alignment, the scapulae were drawn into a retracted/adducted position. The FHRS sitting posture was defined as a position of relaxed, unsupported, slumped sitting. This was characterized by a protruded cervical spine, protracted/abducted scapulae and thoracolumbar flexion. Each subject was cued to maintain the head and eyes level in the transverse plane by focusing his or her gaze on a mark on the wall. The RCS posture was defined as an accentuation of the NCS posture to the extent each subject's maximal cervical retraction range of motion permitted. The scapular position for the RCS was unchanged from the NCS posture. (Figure 1) In each of the postures, the subjects were seated unsupported on a table with feet positioned on a stool for stability.

An investigator was charged with visually monitoring each subjects' sitting posture under each condition to assure the criteria of the condition was maintained throughout each five-minute period. Verbal and tactile cues were provided to each subject as needed throughout the test period to maintain the designated posture. All subjects were successful in maintaining each posture for the required five minutes. However, most subjects found the RCS posture more challenging and few required cuing to maintain the posture. The RCS posture was likely more challenging due to the novelty of the posture and the maintenance of the end ranges inherent to the RCS posture.

Strength testing of the dominant shoulder external rotators was performed using a Micro-FET3 Hand Held Muscle Testing Dynamometer (HHMTD) (Hoggan Scientific Salt Lake City, UT). Cools et al[11] determined the protocol followed in the study to be reliable for testing the strength of the shoulder external rotators using the Micro-FET3. In addition, ICC values of 0.89-0.99 have been reported for intrasession reliability for shoulder external rotation strength testing utilizing a HHMTD.[12-15] Strength testing consisted of three five second "make" tests for shoulder external rotation. "Make" testing has been demonstrated to be a more reliable test of shoulder external rotator strength than a "break" test although less force is produced with the method.[14,16-18]

Each subject was instructed to provide a maximal effort for five seconds while the tester maintained

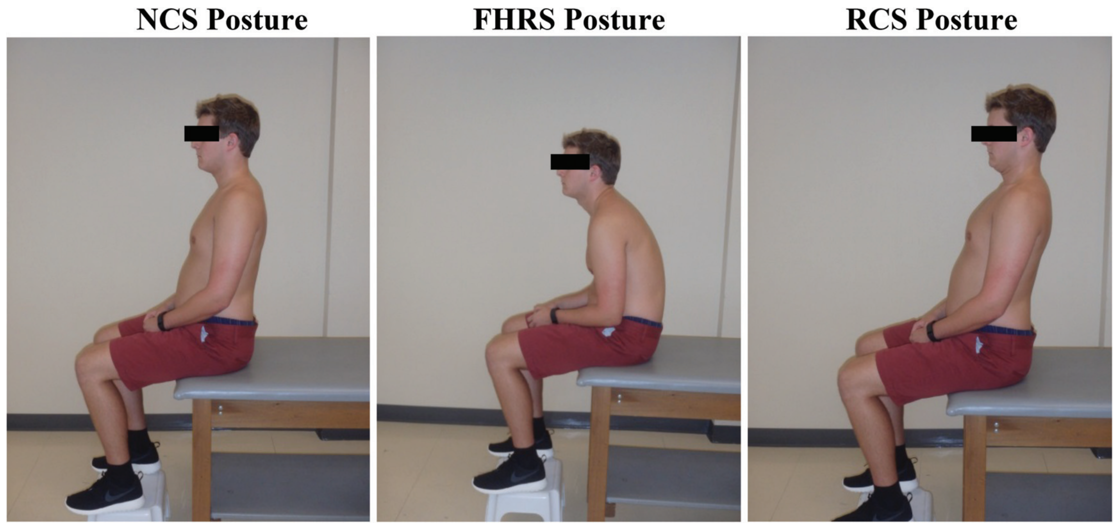

Figure 1. ***NCS (Neutral Cervical Sitting) Posture:*** *Defined by the vertical alignment of the tragus of the ear, bodies of the cervical vertebrae, acromion of the scapula, coronal mid-line of the thorax with the maintenance of the lumbar lordosis.*
FHRS (Forward Head Rounded Shoulder) Sitting Posture: *Defined as a position of relaxed, unsupported, slumped sitting. A protruded cervical spine, protracted/abducted scapulae and thoracolumbar flexion characterized the FHRS sitting posture.*
RCS (Retracted Cervical Sitting) Posture: *Defined as an accentuation of the NCS posture to the extent each subject's maximal cervical retraction range of motion permitted.*
All shoulder external rotator muscle strength testing was performed with the subject in the NCS posture.

the static position of the HHMTD. A 10 second rest period separated each of the three trials. The subjects' upper extremity position for strength testing was 0 degrees of glenohumeral joint abduction, 0 degrees of glenohumeral joint external rotation and 90 degrees of elbow flexion. The HHMTD was held on the dorsum of the distal forearm 2 cm proximal to subjects' radial styloid process. A warm-up of 15 active IR/ER movements were performed from the testing position followed by three sub-maximal practice strength testing trials to familiarize the subjects to the testing protocol prior to the initial NCS condition. All strength testing was performed with the subject in the NCS posture in order to standardize the testing position regardless of the preceding posture.

Study approval was granted by the Misericordia University Institutional Review Board. Informed consent was obtained and the rights of the subjects protected.

RESULTS

External rotator mean strength values are provided for each of the postural conditions. (Table 2) Mean external rotator strength values for each postural condition were normalized for each subject to his or her initial NCS posture strength mean. (Table 3) (Figure 2) Strength values were normalized due to the wide variation in shoulder external rotator strength among subjects. The normalized external rotator strength mean values were calculated by obtaining the mean of the three trials for each subject and each condition and dividing by the mean of each subjects 1st NCS trials. ANOVA (Table 4) and paired sample testing (Table 5) demonstrated a significant decline in shoulder external rotator strength following the FHRS posture compared to each of the

Table 2. *Non-normalized External Rotator Strength (pounds)*

Non-normalized External Rotator Strength (pounds)	Mean	SD	High	Low
All Conditions	19.48	±5.03	37.7	8.7
1st NCS	20.13	±5.09	37.7	11.2
RCS	19.81	±5.14	37.3	11.4
2nd NCS	19.42	±4.93	34.2	10.3
FHRS	18.55	±4.84	32.6	8.7

1st NCS: Neutral Cervical Sitting
RCS: Retracted Cervical Sitting
2nd NCS: Neutral Cervical Sitting
FHRS: Forward Head Rounded Shoulders

Table 3. *Normalized Strength Means to 1st NCS Means*

Normalized Strength Means	N	Minimum	Maximum	Mean	Std. Deviation
1st NCS	100	1	1	1	.00
RCS	99	.76	1.26	.99	.09
2nd NCS	100	.78	1.22	.97	.09
FHRS	100	.68	1.29	.92	1.09

1st NCS: Neutral Cervical Sitting
RCS: Retracted Cervical Sitting
2nd NCS: Neutral Cervical Sitting
FHRS: Forward Head Rounded Shoulders

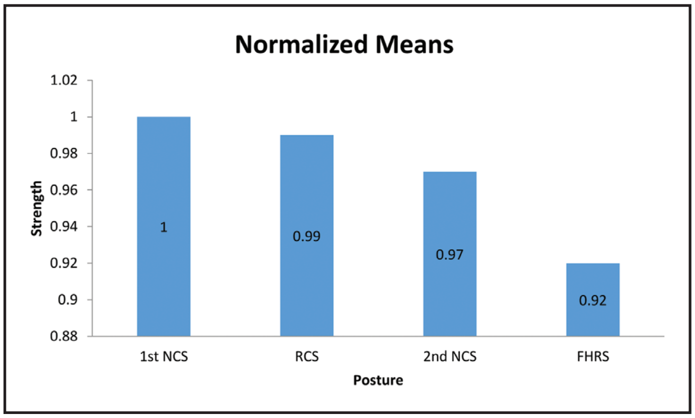

Figure 2. *Strength values were normalized due to the wide variation in shoulder external rotator strength among subjects. The normalized external rotator strength mean values were calculated by obtaining the mean of the three trials for each subject and each condition and dividing by the mean of each subjects 1st NCS trials. The normalized shoulder external rotator strength means following five minutes in the FHRS sitting posture indicate an 8% decline compared to the shoulder external rotator strength means following five minutes in the 1st NCS posture.*

Table 4. *ANOVA between Group Normalized Strength Means (1st NCS, RCS, 2nd NCS, FHRS)*

ANOVA	Sum of Squares	df	Mean Squares	F	Sig
Between Groups	.332	3	.111	16.047	.000
Within Groups	2.726	395	.007		
Total	3.059	398			

1st NCS: Neutral Cervical Sitting
RCS: Retracted Cervical Sitting
2nd NCS: Neutral Cervical Sitting
FHRS: Forward Head Rounded Shoulders

mean strength values following the 1st NCS, RCS and 2nd NCS postures ($p < .05$). No significant difference was detected among the normalized strength means for 1st NCS, RCS and 2nd NCS postures ($p > .05$).

Table 5. *Paired Samples Test between 2nd Neutral Cervical Sitting and Forward Head Rounded Shoulder Normalized Strength Means*

Paired Samples Test	Mean	St. Dev	St. Error	t	df	Sig (2-tail)
2nd NCS-FHRS	.869	1.76	.176	4.934	99	.000

2nd NCS: Neutral Cervical Sitting
FHRS: Forward Head Rounded Shoulders

A frequency analysis revealed that 36% of the subjects demonstrated greater than 10% decline in shoulder external rotator strength following 5 minutes in the FHRS posture. The 10% decline was subjectively determined by the researchers to attempt to identify the presence of a sub-population of subjects experiencing a larger magnitude of strength decline consistent with the authors' clinical observations. The average percentage strength deficit of those with greater than 10% decline was 19%.

DISCUSSION

The FHRS sitting posture is characterized by scapular protraction, lower cervical flexion and upper cervical extension.[19] Previous studies have focused on the influence of scapular position on shoulder muscle strength.[4-6] Smith et al[6] reported a 20% decline in external rotator strength when tested with the scapula protracted and the shoulder flexed to 90 degrees and externally rotated to 90 degrees compared to strength testing with the scapula in the neutral position. Smith et al.[6] speculated the decline in external rotator strength was likely due to biomechanical factors effecting the scapulothoracic and rotator cuff musculature. The ability of the scapulothoracic musculature to stabilize the scapula and provide a firm base for the function of the rotator cuff may have been compromised in the protracted scapula position and may have resulted in reduced external rotator force production. This factor, when coupled with the relatively shortened position of the external rotator musculature in the testing position, result in length/tension considerations that may have further compromised force production.[6]

The results of the current study demonstrate an average decline of 8% in external rotator force production in response to five minutes in the FHRS sitting posture. Furthermore, 36% of the subjects experienced greater than a 10% decline in strength. The scapular and rotator cuff length/tension biomechanical explanations offered by Smith et al for the strength decline in their investigation are less influential considerations in the present study. Inherent to the design of the present study, all shoulder external rotator strength testing was performed in the NCS posture that place the scapular and rotator cuff musculature at a consistent length minimizing length/tension variability in that region.

Although, the intent of the current study was to identify whether shoulder external rotator strength was influenced by cervical spine positioning inherent to various sitting postures and not to determine the cause of the decline, it is interesting to speculate possible causes in order to direct future research. The authors also suspect a biomechanical contribution to the shoulder external rotator muscle strength decline but one occurring at the cervical spine, therefore, indirectly influencing the shoulder complex. Given the FHRS sitting posture resulted in a transient strength decline of the shoulder external rotators, the authors surmise the strength decline may be related to intermittent compression of the C5 nerve root, possibly resulting in a temporary conduction block. A C5 nerve root conduction block could affect the peripheral nerves that receive predominantly C5 contribution, namely the suprascapular and axillary nerves. These nerves innervate the shoulder external rotator muscles, specifically the infraspinatus and teres minor.

The lower cervical flexion that accompanies the FHRS sitting posture has been estimated at $6.3 \pm 4.1^{\circ}$ at the C4/C5 level by Ordway.[20] A study by Anderst et al[21] offers additional information that may shed insight on a potential explanation for C5 nerve root compression through an intervertebral foramenal stenosis mechanism with the lower cervical flexion accompanying the FHRS sitting posture. An anterior shear of C4 on C5, on the magnitude of 33%, was reported to occur accompanying end range cervical flexion.[21] This anterior shear is likely to result in a narrowing of the anterior/posterior dimension of the intervertebral foramen as the inferior articular process of C4 moves toward the posterior aspect of the C5 uncovertebral joint. Although, gross cervical flexion is not identical to the lower cervical flexion which accompanies the FHRS sitting posture, similarities in kinematics do exist. Consequently, a foramenal stenosis at C4-C5 may be created by the lower cervical flexion and resultant shear from time spent in the FHRS sitting posture, which in turn, may be a potential source of C5 nerve root compression and a possible explanation for the decline in shoulder external rotator strength found in the current study.

Furthermore, Topp and Boyd[22] reported compressive forces between 20-30 mmHg can impair neural blood flow, and subsequently, may compromise nerve function. Short term changes in neural blood flow are believed to reverse once the compression is removed without residual nerve damage. However, compressive forces of 50 mmHg, for periods as brief as two minutes, have been shown to result in damage to the myelin and axon. Garfin et al[23], using a pig model, demonstrated a diminution of nerve conduction in both afferent and efferent nerve fibers in response to 75-100 mmHg of compression. The magnitude of the compression represented the mean of the pig's arterial blood pressure. Garfin[23] also reported a return to near normal nerve function one and a half hours following release of two hours of the compression. The previous studies suggest a threshold exist where a level of compression may result in a temporary disruption of nerve function without resultant nerve damage.[22,23] Therefore, the authors surmise temporary nerve compression may be the reason for the shoulder external rotator strength decline demonstrated in the study.

Based on Thompson and Kopell,[24] the authors also offer traction to the suprascapular nerve as a possible explanation for the decline in shoulder external rotator strength in response to the FHRS sitting posture. Thompson and Kopell[24] suggest the scapular protraction that accompanies the FHRS sitting posture may result in traction to the suprascapular nerve. Since the contributing nerve roots of the brachial plexus are anchored proximally by the cervical spine and the suprascapular nerve is anchored distally at the suprascapular notch, it can be tractioned as the scapula moves anteriorly. Rydevik et al[25] report venular stasis to be induced in a nerve that has undergone a tensile stress resulting in a strain of 8%. Topp and Boyd report a 6-8% strain to a nerve results in transient physiologic changes.[22] Furthermore, Rydevik et al[25] report a complete "standstill" in intraneural blood flow in response to a traction force resulting in a 15% strain, a strain that also leads to a loss of nerve conduction and muscle function. The vascular compromise and consequent neural dysfunction that has been reported as a result of neural tension warrants consideration as a potential cause of the shoulder external rotator strength decline observed in the study. However, once again, due to the nature of the strength decline observed, the magnitude of the traction would likely have been enough to impair neural function, yet not to the extent to result in permanent neural damage.

A primary limitation of the study is that the subjects were healthy 20-26 year old adults without significant history of previous cervical pathology and normal range of motion. This fact compromises the ability to generalize the findings to an older population with more advanced cervical degenerative changes and hypomobility. Additionally, the study only examined the effects of five minutes of cervical posturing and therefore cannot make assumptions regarding the effects of longer or shorter cervical posturing time frames.

The authors recommend that future research should focus on the particular cause of the shoulder external rotator strength decline in response to the FHRS posture when controlling for scapula position. This could include future research to examine the specific effect of the anterior shear of C4 on C5 on the cross sectional area of the intervertebral foramen during the FHRS sitting posture.

The authors would also like to point out a practical implication of the study's findings and give the readers something to ponder. Imagine a baseball pitcher sitting in the dugout in a FHRS sitting posture expected to return to the field to throw a 90 mph fastball. One would suspect that this player may be at risk for compromised performance or potential injury if subjected to a possible 19% decline in shoulder external rotator strength; a strength decline that may be preventable by merely modifying cervical posture.

CONCLUSION

The results of the study indicate that shoulder external rotator strength did not significantly decline in response to five minutes in either the 2nd NCS or RCS postures. However, subjects demonstrated an average eight percent decline in shoulder external rotator strength in response to five minutes in a FHRS sitting posture. Furthermore, a sub-population of subjects (36/100) was identified that demonstrated a decline in shoulder external rotator strength of greater than ten percent with an average decline of 19% after positioned five minutes in a FHRS sitting posture. The authors believe that this finding is clinically relevant in that a 19% decline in external rotator strength may alter the external to internal rotator cuff strength ratio and is likely to compromise shoulder function and performance. Therefore, clinicians should be more conscious of the influence of cervical posture when examining the cervical spine and/or the shoulder since a FHRS sitting posture may result in a significant decrease in shoulder external rotator strength due to the possible factors discussed.

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